Agricultural High-Quality Development in Northwest China: Trends and Disparities

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Abstract. This study analyzes agricultural high-quality development in the five northwestern provinces of China—Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang—across five key dimensions: innovation, coordination, green development, openness, and sharing. From 2011 to 2023, the study shows overall improvement, with Shaanxi leading, but significant regional disparities persist, particularly between Shaanxi and lagging provinces like Qinghai and Xinjiang. Kernel density estimation and σ-convergence analysis reveal early convergence followed by widening disparities after 2020. These findings emphasize the need for targeted, region-specific policies to address persistent disparities and foster sustainable agricultural growth in the region.

Keywords: Agricultural Development , Regional Disparities, Sustainable Growth

1 Introduction

Agricultural development is a crucial aspect of China's socio-economic progress, especially in its rural regions. In recent years, the concept of agricultural "high-quality development" has garnered increasing attention from policymakers and researchers alike. This concept goes beyond mere production growth[4], focusing on sustainability, innovation, coordination, and the equitable distribution of benefits across society. It encompasses several dimensions such as technological advancement, ecological protection, and market integration[7]. While agricultural modernization and rural revitalization strategies have propelled growth in various regions, significant disparities still exist between the provinces, particularly in the northwestern areas of China.

The northwest region of China, which includes Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang, is home to unique agricultural challenges. These provinces face ecological fragility[5], water resource scarcity, and regional imbalances in economic development. Furthermore, their agricultural production is highly affected by natural conditions, such as the arid climate and limited fertile land. Despite these challenges, the region remains an important agricultural base for China's distinct agricultural products[6].

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However, existing research on agricultural high-quality development in China has predominantly focused on eastern and central regions, with limited studies on the northwestern provinces. The majority of the research in these regions either examines individual aspects of agricultural development[1], such as innovation or ecological sustainability, or is regionally focused without a comprehensive, comparative framework. This study seeks to fill this gap by developing a robust indicator system to assess the agricultural high-quality development across the five northwestern provinces[3], using a multidimensional approach that integrates innovation, coordination, green development, openness, and sharing.

The purpose of this research is to provide a comprehensive understanding of the agricultural high-quality development in Northwest China, explore the regional disparities, and offer policy recommendations that can help reduce the development gap and enhance overall agricultural sustainability. By doing so, it aims to contribute to the academic literature and support the practical implementation of rural revitalization policies in the region.

2 Research Design

2.1 Study Area

This study focuses on the five northwestern provinces of China—Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang—regions with fragile ecosystems and water resource limitations that heavily influence agricultural development. While agricultural modernization and rural revitalization have improved development quality, significant regional disparities persist due to variations in resources, industrial foundations, openness, and innovation capacity. Therefore, analyzing the factors and levels of agricultural high-quality development in this area is of practical importance.

2.2 Construction of the Indicator System

Table 1. Indicator System for Agricultural High-Quality Development

Primary Indicator	Secondary Indicator	Tertiary Indicator	Attribute	Weight
Level of High-Quality Agricultural Development	Agricultural Innovation Development	Expenditure on Science and Technology Programs	+	0.0473
		Level of Agricultural Mechanization	+	0.0361
		R&D Expenditure Intensity	+	0.0364
		Number of Domestic Patent Applications Accepted	+	0.1025
		Agricultural GDP per Unit Area	+	0.0401
	Agricultural Coordinated Development	Government Fiscal Support for Agriculture	+	0.0176
		Rural Engel Coefficient	-	0.0071

	Consumption Level of Rural Residents	+	0.0240
	Industrial Coordination Level	+	0.0254
	Agricultural Industrial Structure Adjustment Index	+	0.0144
Agricultural Green Development	Fertilizer Use per Unit Area	-	0.0086
	Pesticide Use per Unit Area	-	0.0033
	Agricultural Plastic Film Use per Unit Area	-	0.0044
	Forest Coverage Rate	+	0.0325
Agricultural Open Development	Dependence on Agricultural Product Exports	+	0.1578
	Dependence on Agricultural Product Imports	+	0.3242
Agricultural Shared Development	Urban–Rural Income Ratio	-	0.0101
	Per Capita Disposable Income of Rural Residents	+	0.0300
	Living Standard of Rural Residents	+	0.0193
	Urban–Rural Consumption Gap	-	0.0045
	Number of Village Clinics	+	0.0544

Agricultural high-quality development is a multidimensional concept. Following the principles of scientific validity, systematic coverage, data availability, and comparability, this study constructs an evaluation indicator system from five dimensions: agricultural innovation, agricultural coordination, agricultural green development, agricultural openness, and agricultural sharing[2][5] (As shown in Table 1.). The innovation dimension reflects scientific and technological input and innovation support capacity; the coordination dimension reflects structural optimization and regional coordination; the green dimension reflects resource conservation and ecological protection; the openness dimension reflects market integration and external linkages; and the sharing dimension reflects income growth, public services, and the sharing of development outcomes[1].

2.3 Entropy Weight Method

The entropy weight method was used to assign weights to each indicator. The weight of each indicator is calculated based on the entropy value, which reflects the amount of information the indicator provides. A higher entropy value indicates more uniform distribution, leading to a lower weight.Formula for entropy weight calculation:

$$H_j = -\sum_{i=1}^{n} \frac{p_{ij} \ln(p_{ij})}{\ln(n)} \quad (1)$$

Where:H_j is the entropy of the j-th indicator, p_{ij} is the proportion of the i-th province's value for the j-th indicator,n is the total number of provinces.

2.4 Kernel Density Estimation

KDE is used to estimate the probability density function of data, aiding in the analysis of the distribution of agricultural high-quality development scores. By applying KDE to scores across different years, the dynamic changes and distribution characteristics of agricultural development in the region can be observed.

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \tag{2}$$

Where $f(x)$is the estimated probability density function, $n$is the sample size, $h$is the bandwidth (smoothing parameter), $K$is the kernel function (such as Gaussian kernel), $x_i$is the value of the i-th sample point, and $x$is the point to be estimated.

2.5 σ-Convergence Analysis

The σ-convergence assesses the dispersion of agricultural high-quality development across regions, using metrics such as range, standard deviation, and coefficient of variation to determine if regional disparities are narrowing or widening over time.

$$\sigma_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_{it} - \overline{X_t})^2} \tag{3}$$

The standard deviation for time $t$is denoted by σ_t, X_{it}represents the agricultural development score of province $i$at time t, $\bar{X}_t$is the average agricultural development score of all provinces at time t, and Nrefers to the total number of provinces.

3 Results and Analysis

3.1 Measurement Results of Agricultural High-quality Development

Table 2. Agricultural high-quality development composite score

Province / Year	2011	2015	2019	2023
Shaanxi	0.1169	0.1386	0.1486	0.1692
Gansu	0.0752	0.0982	0.1092	0.1265
Ningxia	0.0762	0.0969	0.1128	0.1251
Qinghai	0.0725	0.0898	0.1063	0.1106
Xinjiang	0.0783	0.0916	0.1025	0.1179

According to the entropy weight method, as shown in Table 2, the composite index of agricultural high-quality development in the five northwestern provinces showed an overall upward trend from 2011 to 2023, indicating a continuous improvement in the quality of regional agricultural development during the study period. The sample mean increased from 0.08383 in 2011 to 0.12989 in 2023, suggesting that the level of agricultural high-quality development in Northwest China improved steadily under the combined effects of agricultural modernization, the implementation of the rural revitalization strategy, and the gradual optimization of resource allocation.

From the inter-provincial perspective, Shaanxi Province remained at a relatively high level throughout the study period. Its composite index increased from 0.11692 in 2011 to 0.16924 in 2023, indicating a clear development advantage. The levels of agricultural high-quality development in Gansu, Qinghai, Ningxia, and Xinjiang also improved, although the magnitude of growth and the final development levels differed across provinces. This suggests that agricultural high-quality development in the five northwestern provinces still exhibited marked regional heterogeneity. Overall, the results indicate that agricultural high-quality development in Northwest China was characterized by simultaneous overall improvement and inter-provincial differentiation.

3.2 Kernel Density Estimation Analysis

To further examine the dynamic evolution of the distribution of agricultural high-quality development in the five northwestern provinces, kernel density estimation was employed.

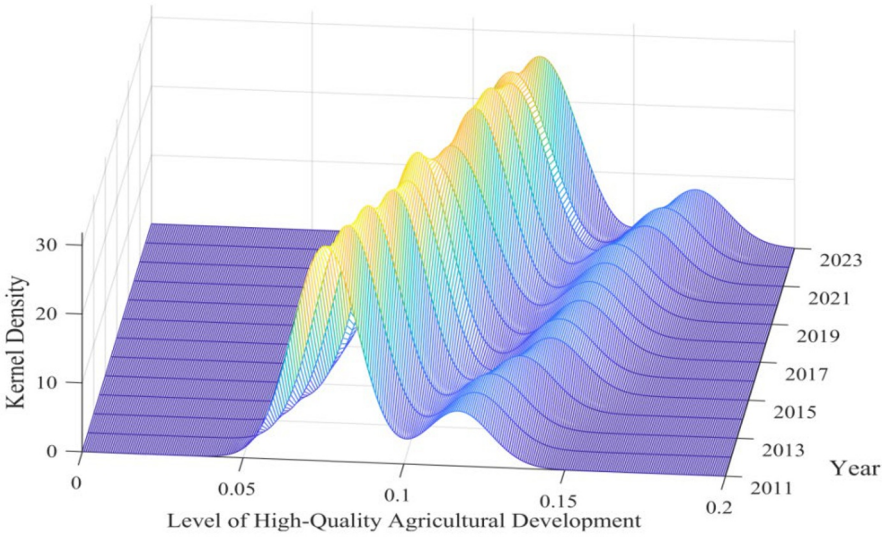

Fig. 1. Kernel Density Estimation of Agricultural Development in Northwest China (2011-2023)

Based on the results shown in Fig. 1. that the kernel density curves shifted noticeably to the right from 2011 to 2023, indicating an overall improvement in agricultural high-quality development across the region. In the early stage of the study period, the distribution was mainly concentrated in the lower value range. Over time, the center of the distribution gradually moved toward the higher value range, and by 2023 the overall development level had increased significantly.

In terms of distributional shape, the main peak of the kernel density curve generally exhibited a pattern of initial concentration followed by subsequent fluctuation, suggesting that inter-provincial disparities experienced a process from relative convergence to partial re-differentiation. In some years, the curves displayed weak bimodal or shoulder features, indicating a certain degree of stratification in agricultural high-quality development and asynchronous development processes across provinces. Overall, the kernel density results suggest that the distribution of agricultural high-quality development in the five northwestern provinces was characterized by simultaneous overall improvement, fluctuating convergence, and partial differentiation.

3.3 Analysis of Spatiotemporal Evolution Characteristics

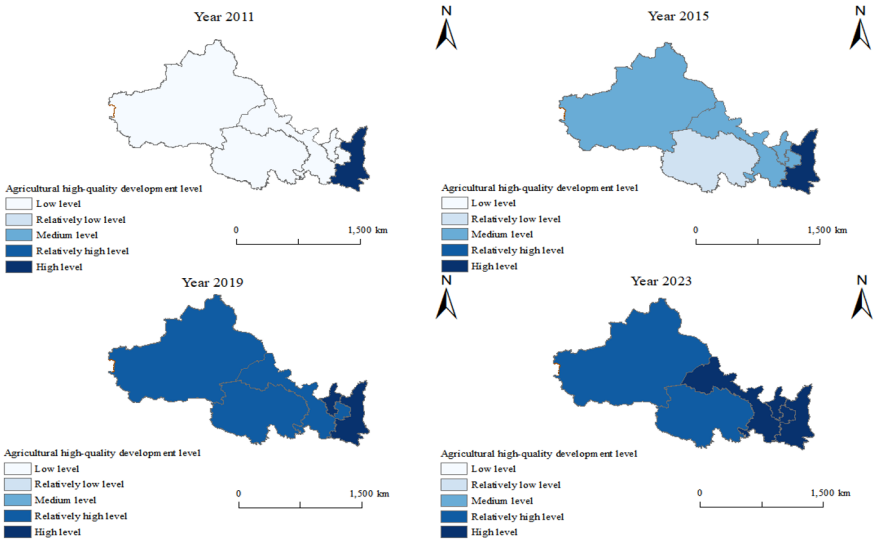

Fig. 2. Spatial Distribution of Agricultural High-Quality Development in Northwest China

As shown in Fig. 2., according to the spatial visualization results for 2011, 2015, 2019, and 2023, agricultural high-quality development in the five northwestern provinces showed a clear upward trend, as reflected by the gradual deepening of map colors across provinces. This indicates a continuous improvement in the overall level of development. In 2011, most provinces were still at relatively low development levels, with Shaanxi showing a more evident advantage. By 2023, most provinces had entered

relatively higher development categories, and the regional overall development level had improved significantly.

From the spatial pattern perspective, Shaanxi remained relatively leading throughout the study period. Gansu Province and Ningxia Hui Autonomous Region were generally at the intermediate level, whereas Qinghai Province and Xinjiang Uygur Autonomous Region continued to improve but still lagged behind in some periods. This indicates that agricultural high-quality development in the five northwestern provinces exhibited a certain degree of path dependence, and regions with better initial conditions maintained their relative advantages during the study period. Overall, the spatial evolution can be summarized as a transition from localized prominence to overall improvement with hierarchical differentiation.

3.4 Analysis of σ-Convergence

Table 3. σ-Convergence Analysis of Agricultural High-Quality Development in Northwest China

Year	Mean	Range	Standard Deviation	Coefficient of Variation
2011	0.08383	0.04443	0.01665	0.19859
2015	0.10300	0.04884	0.01807	0.17546
2019	0.11585	0.04612	0.01670	0.14423
2023	0.12989	0.05861	0.02047	0.15765

To further examine the dynamic evolution of agricultural high-quality development in the five northwestern provinces, σ-convergence analysis was conducted by using the range, standard deviation, and coefficient of variation as key indicators of regional disparities. Generally, if the standard deviation and coefficient of variation decline over time, regional disparities are narrowing and σ-convergence exists; otherwise, regional disparities are widening and σ-convergence does not exist.

The convergence results, as presented in Table 3, that the mean value of the composite index of agricultural high-quality development in the five northwestern provinces continued to rise from 2011 to 2023, indicating an overall improvement in regional development. In terms of convergence characteristics, both the standard deviation and the coefficient of variation generally declined from 2011 to 2020, suggesting that inter-provincial disparities narrowed during this period and that a certain σ-convergence trend was observed. However, after 2020, both indicators increased again, and the range also expanded overall, indicating that regional disparities widened again in the later period and that the convergence trend weakened.

Overall, agricultural high-quality development in the five northwestern provinces did not exhibit stable and continuous σ-convergence during 2011–2023, but instead showed an evolutionary pattern of "early-stage convergence and late-stage fluctuating differentiation." In other words, although the overall level of agricultural high-quality development improved, regional disparities were not completely eliminated, and partial re-differentiation still emerged in the later period. This indicates that differences in resource endowment, development foundation, industrial conditions, and policy im-

plementation capacity continued to affect the convergence process of agricultural high-quality development across provinces.

4 Conclusions

This study examines agricultural high-quality development in five northwestern provinces of China (Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang), focusing on agricultural innovation, coordination, green development, openness, and sharing. From 2011 to 2023, agricultural development improved across all provinces, with Shaanxi maintaining a leading position. The composite index reflected the positive effects of agricultural modernization, rural revitalization, and resource optimization, enhancing productivity and sustainability.

However, significant regional disparities remain. Shaanxi exhibited consistent growth, while provinces like Qinghai and Xinjiang lagged, reflecting differences in resources, industrial infrastructure, and innovation capacities. Kernel density estimation and spatial analysis revealed an overall shift towards higher development scores, though the spatial pattern evolved from localized dominance to broader improvements with hierarchical differentiation.

σ-Convergence analysis showed initial convergence in development levels, followed by divergence post-2020, suggesting that disparities increased again. These fluctuations highlight the influence of local conditions and policy implementation.

In conclusion, while agricultural development improved, regional disparities persist, underscoring the need for tailored policies to address specific regional challenges and reduce inequalities. Future research should investigate the impact of local policies and innovations on furthering equitable agricultural development.

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